Investigation

ACCELERATION

Background Information

When you start your car's engine, fuel and air enter the cylinders, are ignited by a spark, and the mixture explodes. The expanding gases push down on the pistons, which are connected by rods to a crankshaft. The crankshaft converts the pistons' back-and-forth (reciprocating) motion to rotary motion.

You shift into gear and take your foot off the brake. The forces acting upon the vehicle are now unbalanced, and the car begins to move. When you step on the accelerator, you send more fuel to the engine, which creates more unbalanced force, which results in an increase in acceleration.

Speed and acceleration are not the same. Speed or velocity is how fast an object moves and is defined as the distance an object travels divided by the time it takes, or **v = d/t.** For cars, the units of distance are normally miles or kilometers and the units of time are normally hours, so the velocity of a car is usually expressed as miles per hour (mph) or kilometers per hour (kph). Physicists usually express velocity as meters per second. Acceleration is the rate at which velocity changes, i.e., how much change occurs in a given amount of time. The equation for acceleration is:

$$\text{Acceleration} = \frac{\text{final velocity - initial velocity}}{\text{time}} \qquad a = \frac{v_f - v_i}{t}$$

For example, if an object takes 4 seconds to speed up from an initial velocity of 2 meters per second to a final velocity of 10 meters per second, its acceleration is

$$a = \frac{10\ m/s - 2m/s}{4\ s} \qquad a = \frac{8\ m/s}{4\ s} \qquad a = 2m/s/s \qquad a = 2m/s^2$$

In this investigation you will use the motion of a toy car to demonstrate Newton's Second Law of Motion, **F = ma**. Force will be held constant, mass will be varied, and you will measure acceleration.

NAME: CLASS PERIOD: DATE:

ACCELERATION INVESTIGATION CONT.

Problem: *(fill in problem):* _____

_____

Hypothesis: If _____

then _____

Materials

1 toy car (the web sites on page 251 include lessons about models students can build)
5-meter ramp
1 stopwatch or a calculator-based laboratory device equipped with motion and plots software and ultrasonic motion detector.
1 calculator (graphing calculator may be used at teacher's discretion)
1 meter stick
2 flat metal washers or other small weights

Procedure

1. Using a triple beam balance, find the mass of your car.
2. With masking tape, mark off a starting line and a finish line five meters away.
3. Station a timekeeper at the finish line.
4. Hold the toy car on the starting line. At the timekeeper's signal, release the car and let it roll down the ramp. Make sure you do not to give the car a push.
5. The timekeeper should post the time it takes the car to get to the finish line on the data table.
6. Repeat steps 4 and 5 two more times and calculate the averages on the data table.
7. Add a washer or other weight to the car, find the new mass, and repeat steps 4 through 6.
8. Add a second washer or weight to the car, find the new mass, and repeat steps 4 through 6.
9. Using the formulas available in the background information, calculate the velocity, acceleration and sum of external forces.

NAME: CLASS PERIOD: DATE:

ACCELERATION INVESTIGATION CONT.

Observations

	Mass of car (g)	Time	Velocity	Acceleration	Force
Trial 1					
Trial 2					
Trial 3					
Average					
Trial 1					
Trial 2					
Trial 3					
Average					
Trial 1					
Trial 2					
Trial 3					
Average					

Conclusion

1. What is the relationship between the velocity and mass? _____

   _____

2. What is the relationship between acceleration and mass? _____

   _____

3. What is the difference between velocity and acceleration? _____

   _____

4. How does this investigation illustrate Newton's Second Law of Motion? _____

   _____

NAME: CLASS PERIOD: DATE:

ACCELERATION INVESTIGATION CONT.

Application

1. A car accelerates uniformly from rest (0 m/sec) to a speed of 20 m/sec in 15 seconds. Find acceleration. _____

2. If you step on the gas pedal of your car and go from 0 to 60 mph in 5 seconds, what is your acceleration in meters/second^2? _____

3. A car traveling at 5 m/sec accelerates at the rate of 1.5 m/sec^2 for an interval of 2.0 sec. What is its velocity at the end of this acceleration? _____

4. A car can accelerate at an average rate of 2.5 m/s^2. How long will it take to accelerate from 55 m/s to 65 m/s? _____

5. Two cars travel at the same speed. One travels for 15 minutes and goes 40 kilometers, and the other travels for 35 minutes. How far does the second car travel? _____

Going further

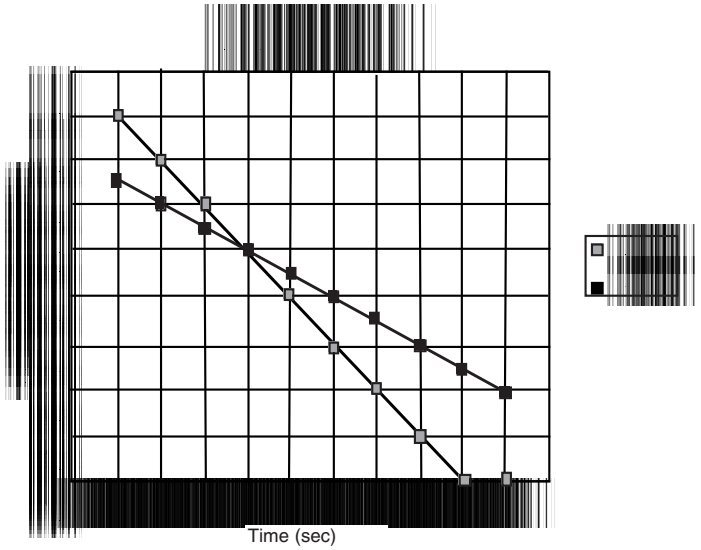
1. Car A has a maximum speed of 40.0 m/s and car B has a top speed of 36.0 m/s. If both cars are moving at top speed and car B is 400 m ahead, how long will it take car A to catch car B? _____

2. Starting from rest, a car accelerates to 72 kph in 4.0 sec. Assuming acceleration is constant, what is the rate of acceleration? _____

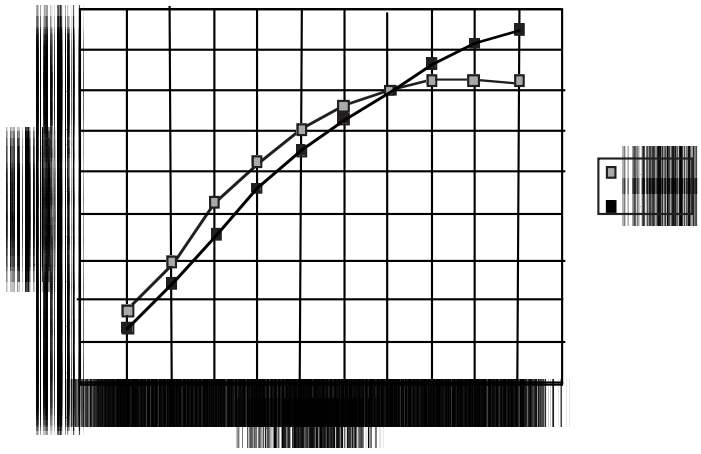
ACCELERATION INVESTIGATION CONT.

3. From the driver's point of view, the best balance between speed and efficiency is achieved by driving "smoothly," that is, by avoiding sudden acceleration and deceleration. Besides putting strain on the electrical and mechanical systems of a car, sudden acceleration and deceleration waste a lot of energy. Graphed below is the performance of two drag cars (A & B).

Time (s)	Acceleration (m/s/s)	
	car A	car B
1	16	13
2	14	12
3	12	11
4	10	10
5	8	9
6	6	8
7	4	7
8	2	6
9	0	5
10	0	4



Time (s)	Velocity (m/s)	
	car A	car B
1	16	13
2	30	25
3	42	36
4	52	46
5	60	55
6	66	63
7	70	70
8	72	76
9	72	81
10	72	85



NAME: CLASS PERIOD: DATE:

ACCELERATION INVESTIGATION CONT.

a. Which car is in the lead off the starting line and why? _____

_____

b. What is the average rate of acceleration for car A and car B at 10 seconds? Show your work.

acceleration for car A

acceleration for car B

c. Using $v_f = v_i + at$, calculate the velocity for each car at 10 seconds? Show your work.

velocity for car A

velocity for car B

d. How far has each car gone at the end of 10 seconds? _____

_____

e. This drag race is over 1/4 mile (420 meters). Which car _____
won the race? Explain your answer in relation to acceleration and velocity. _____

_____

_____